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THE PLANKTON AND THE PROPERTIES OF THE SURFACE WATERS OF THE PUGET SOUND REGION

By

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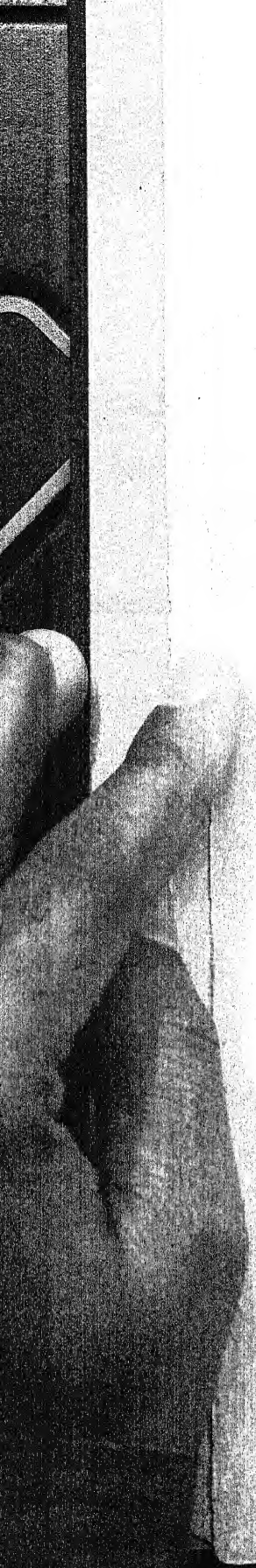

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The Plankton and the Properties of the Surface Waters of the Puget Sound Region

BY

THOMAS G. THOMPSON and LYMAN D. PHIFER

INTRODUCTION

In order to obtain, as nearly as possible, a simultaneous composite of the variations in the physical and chemical properties and plankton of the inland surface waters of the San Juan Archipelago, Puget Sound and Hood Canal, a continuous cruise was made on the *Catalyst*, June 27-29, 1933. This cruise extended for approximately 400 miles from Friday Harbor in the San Juan Archipelago to the heads of Puget Sound and Hood Canal and return, samples being collected about once an hour. Wide variations in the chemical and physical properties of the waters as well as an abundance of biological forms were found. These are reported and discussed below, and include: Temperature, chlorinity, dissolved oxygen, phosphates, silicates, nitrites, and plankton; also, the contour of the bottom over the routes traversed.

METHODS AND PROCEDURE

Samples for analysis were secured from a seacock, especially installed for the purpose of obtaining samples while under way. The intake is situated two meters below the water line in the forward part of the boat.

All the analyses of the waters were made in the laboratory of the *Catalyst* during the cruise. The various procedures used have been described in papers previously published by the Oceanographic Laboratories.

Soundings were made by means of a fathometer, three soundings being taken each minute, the equivalent of about 23 soundings per nautical mile or a sounding about every 85 meters.

The plankton was collected continuously during the entire cruise by the device described by Phifer. (1) The plankton secured between any two stations at which chemical and physical data were taken,

was considered a sample, with the exception of Hood Canal where, on three occasions, more than one plankton sample was secured between the chemical and physical stations. All samples were preserved by the usual methods. The collected material was thoroughly mixed and suitable samples examined to determine the genera and species present in the area and the dominant species in the channels traversed.

DESCRIPTION OF REGION

The areas investigated are generally referred to as the San Juan Archipelago and the Puget Sound region, and are inland waters connected with the Pacific Ocean by the Strait of Juan de Fuca. The locations of the areas are illustrated in figures A, B, and C, the continuous line designating the course followed from Reid Rock in the San Juan Archipelago to the head of Case Inlet and the dotted line showing the return cruise.

In figure D is given a graph of the averages of the soundings obtained during the cruise. This graph illustrates the general nature of the bottom contour.

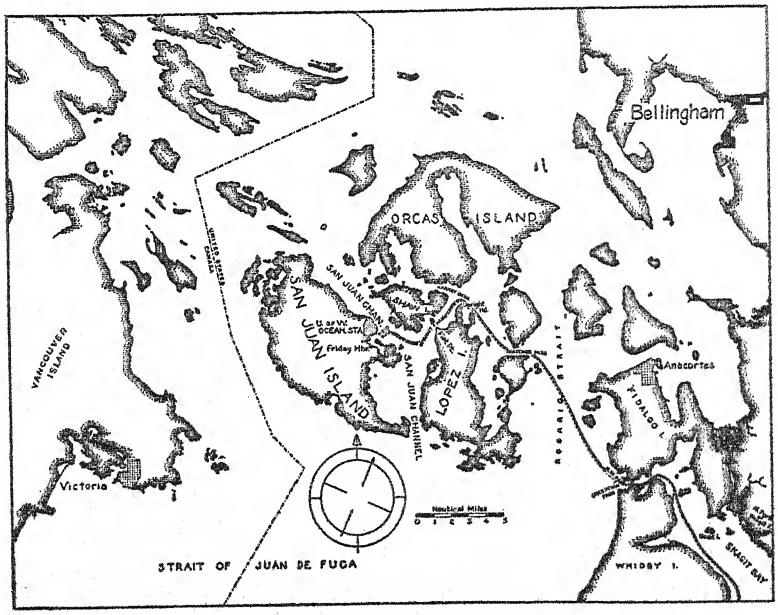

Fig. A. Chart of the San Juan Archipelago, showing track of the *Catalyst* from Reid Rock through Deception Pass and into Skagit Bay.

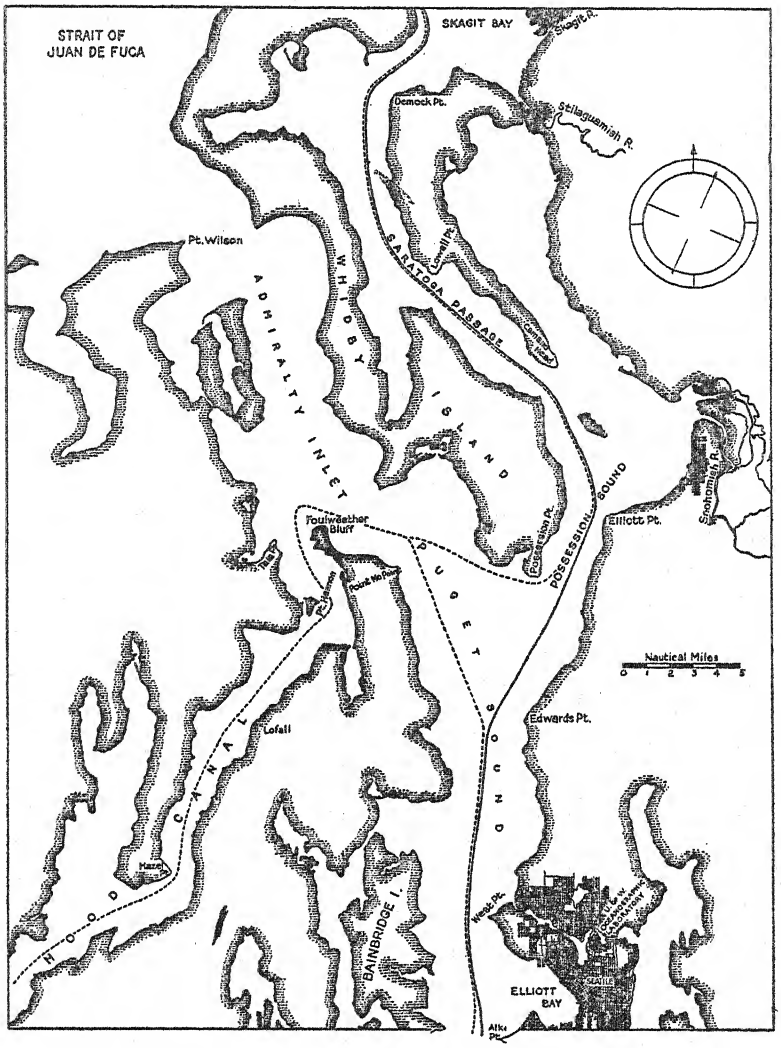

Fig. B. Chart of the northern portion of Puget Sound and Hood Canal, showing track of the *Catalyst* from Skagit Bay to Alki Point and in Hood Canal.

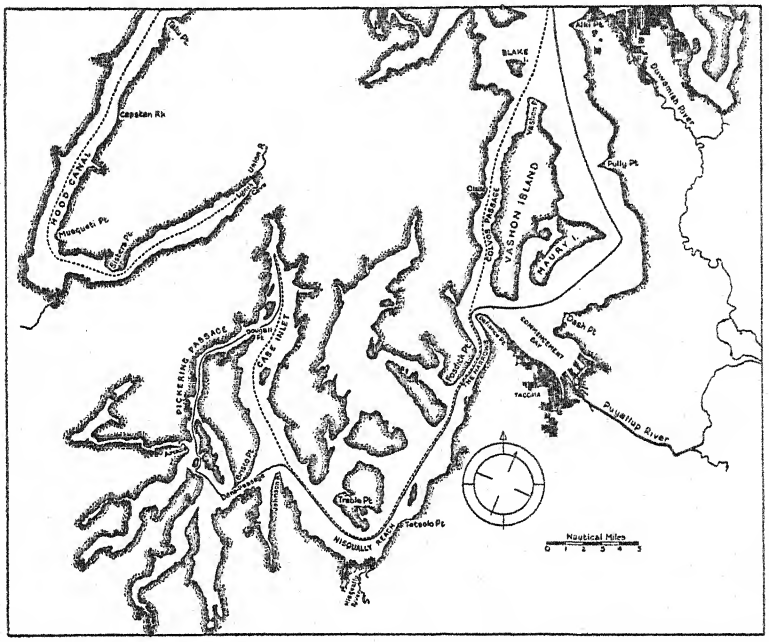

Fig. C. Chart of the southern section of Puget Sound and Hood Canal, showing track of the *Catalyst* to the headwaters of Hood Canal and Puget Sound.

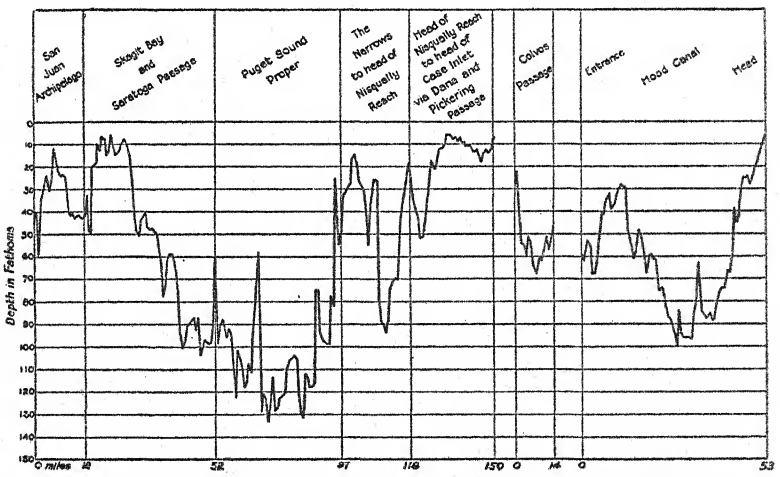

Fig. D. Graph showing the variations in the depths of the waters in the regions traversed.

San Juan Archipelago. A description of the Strait of Juan de Fuca and the channels of the San Juan Archipelago has been recently published. (2)

Puget Sound extends about 53 miles in a general southerly direction from Point Wilson and then turns southwestward for about 30 miles, expanding into numerous inlets and passages. The northern boundary of Puget Sound, where it joins the Strait of Juan de Fuca, is approximately 48° 10′ north latitude, and the southern boundary at the head of the Sound is 47° 10′ north. Puget Sound may roughly be divided into three portions—the northern section extending from Possession Point to the junctions with the Strait of Juan de Fuca and the San Juan Archipelago, the central section from Possession Point to Point Defiance, and the southern section which includes the various estuaries and passages at the head of the Sound south of Point Defiance.

Admiralty Inlet. The northern section of Puget Sound has two branches, the one to the west being Admiralty Inlet which connects with the southeastern part of the Strait of Juan de Fuca, extending northwest-southeasterly for 18 miles to Point No Point and averaging 4 miles in width. This passage is the main waterway connecting Puget Sound with the Strait and in it the tidal currents vary from 2 to 5 knots. The entrance to Admiralty Inlet from the Strait of Juan de Fuca is characterized by a distinct threshold, over which the water has an approximate depth of 30 fathoms. The depth in mid-channel from the entrance to Point No Point varies from 24 to 101 fathoms.

Skagit Bay, Saratoga Passage, and Possession Sound. The eastern branch of the northern section comprises Skagit Bay, Port Susan, Saratoga Passage, and Possession Sound. Skagit Bay is connected with the San Juan Archipelago by means of Deception Pass, a narrow passage that is about 2 miles long, 200 yards wide at the narrowest point, and 4 fathoms deep at the shallowest. The tidal currents in the Pass attain a velocity of from 5 to 8 knots at strength, when strong eddies occur along the shores. The large volume of water rushing through the Pass with each tide is well mixed due to the configuration of the passage and the great velocity of the current. The flood tide not only enters at Deception Pass but also at the southern extremity of Possession Sound. The latter and its tributaries are bounded on the east by the mainland from which discharge three fairly large rivers—the Skagit, Stillaguamish, and Snohomish whose deltas form exten-

sive mud flats that are bare at low tide. Throughout the area, the mid-channel depth gradually increases from 7 fathoms at the northern end of Skagit Bay to 120 fathoms at the junction of Possession Sound and the middle section of Puget Sound at Point Possession. The tidal currents, which are of considerable velocity, vary with the width and depth of the channel's cross section.

Puget Sound Proper. From the juncture of the two northern arms of Puget Sound at the southern end of Whidby Island, the main channel extends southerly for about 35 miles and then southeast 5 miles to Point Defiance. The channel averages 3 miles in width and the mid-channel depth is seldom less than 100 fathoms, deepening to 142 fathoms off Alki Point. The eastern shore of the middle section is without indentations except for Elliott and Commencement Bays into which the Duwamish and Puyallup Rivers, respectively, discharge. The western shore has numerous inlets, especially to the west of Bainbridge Island which lies in the northwestern part of this central area.

Colvos Passage. Farther southward are Vashon and Maury Islands; between the former and the western shore of the mainland lies Colvos Passage. This is a straight narrow passage running north and south for about 11 miles, averaging 1 mile in width and having a mid-channel depth between 50 and 60 fathoms except at the southern end where it shoals to about 25 fathoms.

The Narrows and Head Waters of the Sound. South of Point Defiance is the southern section of Puget Sound which extends southwesterly and is composed of numerous passages and inlets. Immediately south of Point Defiance are the Narrows, a pass that is 5 miles in length, ¾ of a mile wide, and averages 25 fathoms deep. These Narrows are the only entrance to the southern part of the Sound, and the tidal currents at the strength of the spring tides reach a velocity of 5 to 6 knots. Within a relatively short distance from either end of the Narrows are depths of 100 fathoms or more; thus, the rather sudden shoaling, together with the strong tidal currents, causes considerable turbulence here. South of the Narrows, many inlets form, which at their heads generally terminate in extensive mud flats into which small streams enter. In general, these inlets are from 5 to 100 fathoms deep and are connected by numerous passages of varying widths and depths.

Hood Canal. Between Foulweather Bluff and Tala Point, Hood Canal extends westward from the southern part of Admiralty Inlet. The Canal is the longest inlet of Puget Sound, extending 44 miles in a southerly direction, then turning sharply to the northeast for 11 miles. The average width of the inlet is about 1½ miles; the narrowest width of a half mile is abreast of Sisters Point. At the entrance, the mid-channel depth of the Canal is 74 fathoms, but this decreases fairly rapidly to form a threshold with a mid-channel depth of 29 fathoms off Lofall. From there, the mid-channel depths rapidly increase to about 100 fathoms and then gradually decrease up to the head which is a mud flat, the delta of the Union River. Along the entire western shore of the Canal, a number of small rivers discharge from the Olympic Mountains, each building a small delta. The tidal currents of the inlet are weak, the strength of the spring tides off Point Hannon having a velocity of little more than 1 knot, the maximum for Hood Canal.

The track of the *Catalyst* during the cruise is shown in figures A, B, C. It began at Reid Rock in San Juan Channel and followed a mid-channel course to Flat Point, through Upright Channel to Upright Head, down Harney Channel, through Thatcher Pass into Rosario Strait and down the Strait to Northwest Pass. Here a stop of 25 minutes was made to wait for the tide to change from ebb to flood in Deception Pass, after which the vessel went through the Pass into Skagit Bay, Saratoga Passage, and Possession Sound. In the middle section of Puget Sound, the eastern passage was followed to Point Defiance, from there through the Narrows, Nisqually Reach, Dana and Pickering Passages to the head of Case Inlet, then through the latter to its juncture with Nisqually Reach. From this point, the course was retraced to Point Defiance and thence to Colvos Passage which was followed to its juncture with the middle section of Puget Sound off Blake Island. Here again the course was retraced to Edwards Point, changing then to Foulweather Bluff and to the head of Hood Canal where the course was retraced to the Canal's entrance. Puget Sound was crossed to Possession Sound and the same course as previously outlined was followed to Reid Rock where the cruise had started.

EXPERIMENTAL

The physical and chemical data are presented in tables 1 and 2. These data are graphically illustrated in figure E.

TEMPERATURE

The lowest temperatures of the cruise were obtained in the waters of the San Juan Archipelago. The factors producing these low temperatures have been previously described (2) and are explained by the upwelling of the cold subsurface waters of the Pacific Ocean and the eventual passage of these waters, which have been mixed with the waters on the continental shelf, into the Strait of Juan de Fuca. The marked irregularity of the bottom of the Strait and the San Juan Archipelago, together with the strong tidal currents, produce decidedly turbulent conditions and thus cause a rather uniform distribution of temperature in the water layers of much of the region.

On passing from the waters of the San Juan Archipelago into Skagit Bay by means of the narrow channel, Deception Pass, a decided change in temperature was noted. The surface waters of this area, together with those of Saratoga Passage, are largely influenced by the discharge of the Skagit and Stillaguamish Rivers. As these rivers discharge into the sea, they pass over mud flats of considerable area. Since, during the late spring and summer months, these flats are warmed by the sun at low tide, the brackish waters flowing over them at high tide are heated and thus the temperatures of the surface water are noticeably increased. These warm diluted water layers float upon the colder and more concentrated sea water in the deeper parts of Skagit Bay and Saratoga Passage. Increases in temperature of 4° C. over that observed in the San Juan Archipelago were noted. These relatively high temperatures approximating 14° C. continued until Puget Sound proper was reached. The surface waters connecting Puget Sound with Saratoga Passage (Possession Sound) are more or less influenced by the discharge of the Snohomish River which likewise discharges over large areas of mud flats.

For a distance of over 30 miles in Puget Sound proper, the waters showed a temperature decrease, averaging about 1° C., which was attributed to the conveyance of the cold water of the Strait of Juan de Fuca into Puget Sound through the twenty-odd-mile length of Admiralty Inlet. In the Narrows a sudden decrease in temperature amounting to about 3° C. was noted. This was produced by the marked turbulent condition caused by the strong tidal currents and

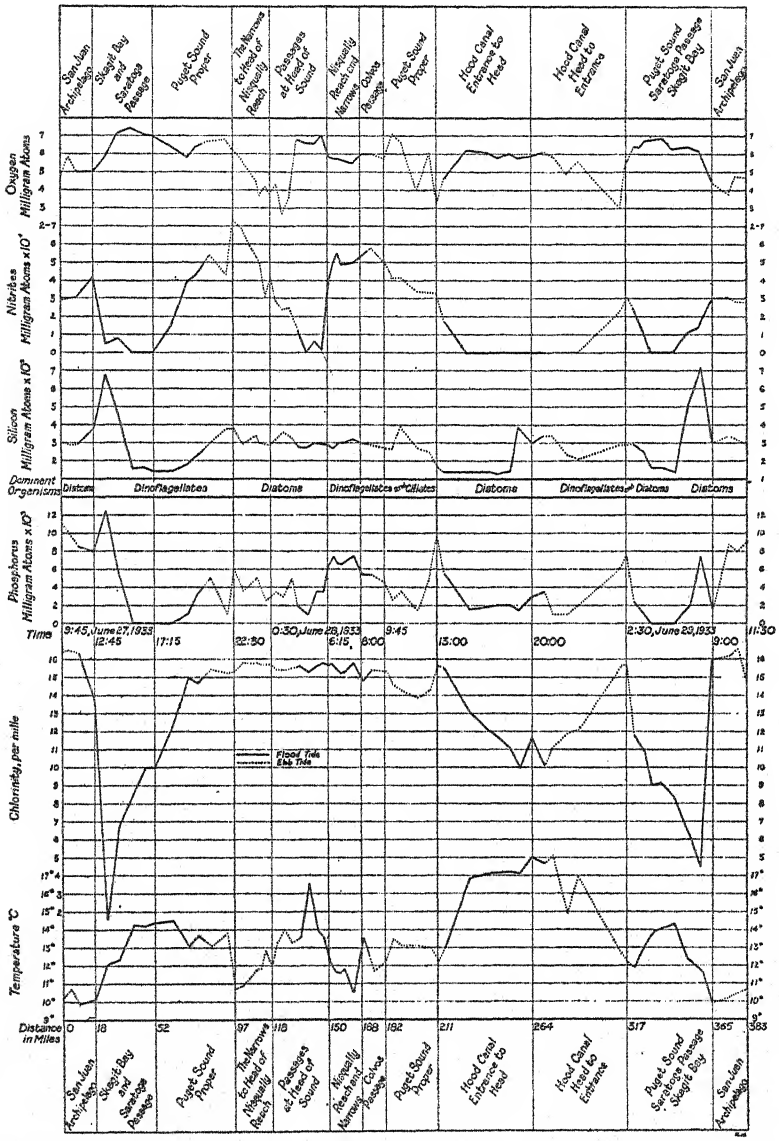

Fig. E. Graph showing the variations in temperature, chlorinity, phosphorus, silicon, nitrites, and dissolved oxygen, together with dominant plankton in the surface waters of the regions traversed by the *Catalyst*. Time of flood tide designated by continuous lines and ebb tide by dotted lines.

TABLE 1.—Temperature, Chlorinity, Density and pH Data of Surface Waters

Cruise: June 27-29, 1933. From Reid Rock, San Juan Channel, to Head of Puget Sound and Hood Canal and return

pH	Density σ_t	Cl. ‰	Temp. °C.	Time	Tide	Location	Tide	Time	Temp. °C.	Cl. ‰	Density σ_t	pH
8.00	22.79	16.40	10.25	9.45	E	Reid Rock	E	11.26	10.70	14.83	20.48	8.10
8.15	22.73	16.50	10.75	10.20	E	Upright Head	E	10.48	10.50	16.55	22.93	8.10
7.95	22.75	16.35	9.89	10.58	E	Thatcher	E	10.18	10.17	16.21	22.52	8.15
8.10	19.64	14.15	10.15	12.38	F	Deception Is.	E	9.04	9.95	15.95	22.17	8.15
7.00	1.78	1.56	12.10	13.24	F	Goat Is.	E	8.29	11.70	4.24	5.57	7.90
8.30	8.99	6.75	12.40	14.15	F	Dennock Point	F	7.25	12.45	6.43	8.51	8.15
8.80	11.06	8.48	14.30	15.23	F	Lowell Point	F	6.15	14.30	8.46	11.03	8.80
8.80	13.15	9.96	14.2	16.13	F	Camano Head	F	5.25	14.10	9.10	11.97	8.60
8.60	13.13	9.95	14.35	16.57	F	Elliot Point	F	4.40	13.85	9.03	11.90	8.40
								(Hood Canal Cruise: Table 1a)				
8.35	16.11	12.15	14.50	18.10	F	Edwards Point	E	11.36	13.12	13.89	18.76	8.10
8.20	20.32	14.98	13.06	19.05	F	West Point	E	10.35	13.12	14.30	19.32	8.10
8.40	19.66	14.63	13.70	19.38	F	Alki Point	E	10.02	13.45	14.63	19.73	8.35
8.40	20.95	15.45	13.10	20.40	E	Pully Point						
8.30	19.09	14.23	13.80	21.50	E	Dash Point						
						Vashon Point	E	9.35	12.20	15.35	21.00	8.10
						Olalla	E	8.55	11.70	15.40	21.11	8.15
8.10	21.10	15.30	10.70	22.23	E	Point Defiance	F	8.05	13.50	14.75	19.91	8.50
8.10	21.80	15.80	10.90	23.00	E	Fosdick Point	F	7.25	10.50	15.80	21.87	8.10
8.10	21.61	15.80	11.80	0.10	E	Tatsolo Point	F	6.23	11.80	15.30	20.93	8.10
8.10	21.43	15.67	11.85	0.30	E	Nisqually Reach	F	6.15	11.60	15.23	20.87	8.20
8.20	21.29	15.70	12.80	0.55	E	Treble Point	F	5.57	11.65	15.72	21.54	8.10
8.20	21.47	15.70	12.00	1.20	E	Johnson Point	F	5.35	12.10	15.70	21.44	8.30
8.10	20.93	15.45	13.30	1.50	E	Brisco Point						
8.10	20.73	15.45	14.00	2.25	E	Arcadia Point						
8.15	20.95	15.50	13.32	2.55	E	Grant						
						Middle Case Inlet	F	5.00	13.65	15.77	21.29	8.40
8.20	21.07	15.62	13.50	3.25	E	Dougall Point	F	4.38	13.90	15.65	21.29	8.40
8.40	20.01	15.30	16.55	4.05	F	Case Inlet Head						

TABLE 1a.—Temperature, Chlorinity, Density and pH Data of Surface Waters

Cruise: June 27-29, 1933. From Reid Rock, San Juan Channel, to Head of Puget Sound and Hood Canal and return

pH	Density σ_t	Cl. ‰	Temp. °C.	Time	Tide	Location	Tide	Time	Temp. °C.	Cl. ‰	Density σ_t	pH
						Possession Point.....	E	4.10	13.05	10.85	14.57	8.30
8.10	17.97	13.30	13.00	12.30	E	Point No Point.....	E	3.20	11.90	11.85	17.14	8.30
8.30	21.34	15.65	12.30	13.05	E	Foulweather Bluff.....	E	2.30	12.10	15.76	21.49	8.10
8.30	21.04	15.50	12.90	13.40	F	Hannon Point.....	E	2.05	12.60	15.65	21.31	8.30
8.50	16.94	13.10	16.80	15.35	F	Hazel Point.....						
8.55	15.53	12.12	17.10	16.54	F	Tekiu Point	E	23.25	16.90	12.10	15.54	8.50
8.60	14.94	11.73	17.15	17.37	F	Capstan Rock.....	E	22.30	14.80	11.90	15.71	8.70
8.30	14.11	11.10	17.20	18.41	F	Musqueti Point	E	21.35	17.05	11.11	14.16	8.70
8.75	12.56	9.97	17.15	19.16	F	Sisters Point.....	F	20.58	16.70	10.06	12.81	8.50
8.80	14.75	11.70	18.00	20.03	F	Lynch Cove						

TABLE 2.—Concentrations of Phosphorus, Silicon, Nitrite Nitrogen and Dissolved Oxygen in the Surface Waters

Constituents reported as milligram atoms per kilogram of water

Cruise: June 27-29, 1933. From Reid Rock, San Juan Channel, to Head of Puget Sound and Hood Canal and return.

Dissolv. Oxygen		NO_2	Si	P						P	Si	NO_2	Dissolv. Oxygen	
% Sat.	mg. at.	10^3	10^2	10^3	Time	Tide	Location	Tide	Time	10^3	10^2	10^3	mg. at.	% Sat.
80	0.456	0.29	2.9	1.10	9.45	E	Reid Rock	E	11.26	0.90	2.8	0.28	0.458	81
100	.565	.30	2.8	0.95	10.20	E	Upright Head	E	10.48	.80	3.1	.28	.473	85
85	.489	.31	2.8	.85	10.58	E	Thatcher	E	10.18	.85	3.3	.31	.368	65
84	.491	.42	3.7	.80	12.38	F	Deception Is.	E	9.04	1.05	3.6	.30	.426	77
102	.683	.05	6.8	1.25	13.24	F	Goat Is.	E	8.29	.75	7.2	.14	.619	94
113	.703	.08	4.6	0.55	14.15	F	Dennock Point	F	7.25	.20	5.2	.11	.637	96
125	.730	None	1.6	None	15.23	F	Lowell Point	F	6.15	None	1.4	None	.622	107
125	.707	None	1.6	None	16.13	F	Camano Head	F	5.25	None	1.6	None	.677	117
123	.696	None	1.4	None	16.57	F	Elliot Point	F	4.40	None	1.6	None	.670	116
										(Hood Canal Cruise: Table 2a)				
116	.633	.15	1.4	None	18.10	F	Edwards Point	E	11.36	.15	2.7	.34	.390	71
105	.870	.39	1.8	0.10	19.05	F	West Point	E	10.35	.35	3.8	.42	.661	121
116	.624	.43	2.3	.35	19.38	F	Alki Point	E	10.02	.25	2.6	.42	.692	128
122	.657	.54	2.9	.50	20.40	E	Pully Point							
123	.663	.43	3.7	.10	21.50	E	Dash Point							
							Vashon Point	E	9.35	.45	2.6	.50	.564	104
							Olalla	E	8.55	.55	2.9	.58	.585	106
108	.608	.73	3.6	.60	22.23	E	Point Defiance	F	8.05	.55	2.9	.51	.596	111
100	.561	.69	2.8	.45	23.00	E	Fosdick Point	F	7.25	.75	3.1	.69	.528	95
79	.436	.53	3.3	.50	0.10	E	Tatsolo Point	F	6.23	.65	2.9	.49	.562	102
66	.361	.50	2.9	.40	0.30	E	Nisqually Reach	F	6.15	.65	2.9	.55	.565	102
77	.414	.31	2.8	.25	0.55	E	Treble Point	F	5.57	.75	2.6	.50	.569	103
67	.369	.41	2.8	.30	1.20	E	Johnson Point	F	5.35	.65	2.9	.41	.576	105
78	.420	.29	3.1	.35	1.50	E	Brisco Point							
50	.264	.24	3.5	.30	2.25	E	Arcadia Point							
64	.339	.25	3.3	.50	2.55	E	Grant							
							Middle Case Inlet	F	5.00	.35	1.6	.02	.691	131
123	.654	.14	2.6	.20	3.25	E	Dougall Point	F	4.38	.35	1.6	.06	.646	123
127	.642	None	2.6	.10	4.05	F	Case Inlet Head							

TABLE 2a.—CONCENTRATIONS OF PHOSPHORUS, SILICON, NITRITE NITROGEN AND DISSOLVED OXYGEN IN THE SURFACE WATERS.

Constituents reported as milligram atoms per kilogram of water.

Cruise: June 27-29, 1933. From Reid Rock, San Juan Channel, to Head of Puget Sound and Hood Canal and return.

Dissolv. Oxygen		NO_2 10^3	Si 10^2	P 10^3	Time	Tide	Location	Tide	Time	P 10^3	Si 10^2	NO_2 10^3	Dissolv. Oxygen	
% Sat.	mg. at.												mg. at.	% Sat.
							Possession Point ..	E	4.10	0.10	2.5	1.0	0.661	115
107	0.594	3.3	2.5	0.50	12.30	E	Point No Point ...	E	3.20	.25	2.9	2.5	.627	108
59	.324	3.3	1.6	.95	13.05	E	Foulweather Bluff.	E	2.30	.75	2.9	3.1	.525	96
83	.446	1.6	1.4	.55	13.40	F	Hannon Point.....	E	2.05	.60	2.9	2.4	.291	54
117	.606	None	1.4	.15	15.35	F	Hazel Point.....	E						
115	.598	None	1.4	.10	16.54	F	Tekiu Point	E	23.25	.20	2.1	None	.554	106
114	.575	None	1.3	.20	17.37	F	Capstan Rock.....	E	22.30	.10	2.3	None	.482	88
112	.593	None	1.4	.20	18.41	F	Musqueti Point ...	E	21.35	.10	3.4	None	.569	107
106	.567	None	3.9	.15	19.16	F	Sisters Point.....	F	20.58	.35	3.4	None	.598	111
113	.582	None	3.0	.30	20.03	F	Lynch Cove.....							

the resultant cooling of the surface waters by the colder bottom water. As the Narrows widened at their southern end, the waters tended to become stratified again, the surface waters gradually increasing in temperature. Fluctuations in temperature were observed in the passages and inlets near the head of the Sound, the highest temperature, 16.55° C., being recorded at the head of Case Inlet.

On the return trip, the waters of the various passages at the head of the Sound showed similar temperature readings as on the incoming trip. However, at the northern entrance to the Narrows (Point Defiance), an increase of 3° C. over the temperature noted the previous evening was recorded. On the ingoing trip, there was an ebb tide running through the Narrows from the south, with resulting turbulence and mixing in the Narrows. On the outgoing trip the tide was flooding and very little turbulence was noticeable at the northern entrance. On passing through Colvos Passage the turbulent condition of the water was likewise manifested by decreases in temperature. In Puget Sound proper the temperatures on the trip returning were much the same as on the ingoing. The warmest waters of the entire region covered by the cruise were encountered in Hood Canal, the highest temperature, 18° C., being observed at the head of the waterway. On returning from the head of Hood Canal to Reid Rock in the San Juan Archipelago the water temperatures were similar to those recorded one or two days previously.

CHLORINITY

With the exception of the Skagit Bay-Saratoga Passage area, the northern portion of Puget Sound proper and the Hood Canal area, the chlorinities were fairly uniform, averaging between 15 $^0/_{00}$ and 16 $^0/_{00}$. The dilution effects of the rivers entering Skagit Bay are illustrated in figure E. The chlorinities of the Hood Canal region gradually decreased from the mouth to near the head, the drop being especially pronounced after passing the threshold near the entrance of the Canal. These lower chlorinities were produced by the dilution effects of the discharge of small rivers at various points. At the head of the Canal a decided shoaling of the waters occurs, and an abrupt increase in chlorinity was observed. This shoaling and the general narrowing of the Canal produce more or less upwelling and turbulence due to the repelling of the tidal surge. The consequent mixing of the bottom and surface water layers was not only manifested by the change in chlorinity but also by the increase in phosphate concentration.

PHOSPHATES

The usual phosphate values previously reported for this season of the year were obtained in the waters of the San Juan Archipelago. However, on entering Skagit Bay from Deception Pass, an unusually high value for phosphate was obtained near the mud flats and in the same locality where abnormally low chlorinity values were found. The phosphate ratio for this station was considerably greater than that obtained in ordinary sea water, and therefore indicates that the sources of phosphate must have been other than sea water. The writers explain this phenomenon by the fact that though the fresh waters of the Skagit River showed only a mere trace of phosphates, they discharge into the sea over extended mud flats and leach the phosphate from decaying organic matter periodically exposed to the air. On the return trip slightly higher chlorinity values were obtained, but the phosphate was still abnormally high, though lower than observed two days previously. In the other portions of Skagit Bay, in Saratoga Passage, and in Possession Sound, as well as in Hood Canal, the surface water was devoid of inorganic phosphorus. Marked fluctuations in the concentration of the element were found in the waters of the other regions.

SILICATES

Very much the same trend was observed for silicates as for phosphates. Near the mouth of the Skagit River the effect of dissolved silicates in the fresh water was very noticeable. Relatively high silicate values were also obtained at the head of Hood Canal. In sailing the length of the Canal on a flood tide the silicate values were found exceedingly low in spite of the discharge of the large number of rivers into the Canal; while returning on an ebb tide, just a few hours later, silicate values were found very much higher.

NITRITES

The nitrites follow the same general curve as the phosphates, except in the Hood Canal area where zero values were obtained throughout. In all of the localities where there was a very marked plankton growth the nitrites were absent.

DISSOLVED OXYGEN

Considerable variations in the dissolved oxygen were noticed, but in regions where the waters were not subjected to marked turbulence the values were fairly uniform. In the San Juan Archipelago, in the narrows, and near the threshold at the entrance to Hood Canal, low oxygen values were obtained, due to the turbulence produced by tidal currents and the resulting dispersion of the various organisms bringing about photo-chemical reactions. The lowest values of the entire cruise were noted near the mouth of a long, narrow, shallow inlet at the head of which is located a large paper mill using the sulfite process. The highest values were obtained in Saratoga Passage during the early afternoon. Two days later when samples were taken in the hours after midnight at the same places and at the same phases of the tide, the oxygen values were slightly lower.

pH VALUES

The pH values given in table 1 have not been corrected for salt error. They were all determined at a temperature of approximately 15° C. The lowest values were obtained in the waters of the San Juan Archipelago with the exception of one sample which was taken near the mouth of the Skagit River and had an exceedingly low chlorinity. The highest values were observed in Skagit Bay, in Saratoga Passage, and at the head of Hood Canal.

PLANKTON

Three groups of microplankton were observed and investigated. Diatomaceae were represented by 17 genera and 41 species; Dinoflagellata, by 10 genera and 18 species; Tintinnoinea, by 7 genera and 17 species.

DIATOMACEAE

Asterionella japonica
Biddulphia longicruris
Cerataulina Bergonii
Chaetoceros affinis
Chaetoceros compressus
Chaetoceros crucifer
Chaetoceros debilis
Coscinosira polychorda
Dactyliosolen mediterraneus
Ditylum Brightwelli
Eucampia zoodiacus
Leptocylindrus danicus
Nitzschia closterium
Nitzschia seriata

Chaetoceros decipiens
Chaetoceros diadema
Chaetoceros eibenii
Chaetoceros lachiniosus
Chaetoceros lorenzianus
Chaetoceros pseudocrinitus
Chaetoceros radicans
Chaetoceros Vanheurckii
Corethron hystrix
Coscinodiscus centralis
Coscinodiscus concinnus
Coscinodiscus excentricus
Coscinodiscus Granii
Coscinodiscus radiatus
Coscinodiscus Wailesii
Rhizosolenia fragilissima
Rhizosolenia hebetata
Rhizosolenia semispina
Rhizosolenia setigera
Rhizosolenia stolterfothii
Sceletonema costatum
Thalassionema nitzschioides
Thalassiosira aestivalis
Thalassiosira condensata
Thalassiosira Nordenskioeldii
Thalassiosira rotula
Tropidoneis antarctica

DINOFLAGELLATA

Ceratium fusus
Ceratium tripos
Dinophysis acuminata
Dinophysis acuta
Dinophysis ellipsoides
Dinophysis sphaerica
Exuviella perforata
Goniaulax spinifera
Gymnodinium lunula
Noctiluca scintillans
Oxytoxum diploconus
Peridinium conicum
Peridinium depressum
Peridinium divergens
Peridinium micrapium
Peridinium obtusum
Phalacroma rotundatum
Protoceratium reticulatum

TINTINNOINEA

Dictyocysta apiculata
Favella serrata
Helicostomella subulata
Parundella major
Stenosemella expansa
Stenosemella punctata
Stenosemella ventricosa
Tintinnopsis beroidea
Tintinnopsis cylindrica
Tintinnopsis karajacensis
Tintinnopsis nitida
Tintinnopsis major
Tintinnopsis nucula
Tintinnopsis radix
Tintinnopsis sacculus
Tintinnus pectinis
Tintinnus rectus

Of the total number of species present and listed above relatively few ever became dominant in the samples taken. In the main, the dominance of one group over another was noticeable in the material, but dominance of species for given portions of the cruise was not so clearly defined. Figure E gives the group or groups of dominant plankton organisms, the first named being the most numerous. If this plankton dominance is compared with the route of the *Catalyst* in figures A, B, C, it will be noticed that the various areas possessed a fairly uniform plankton in the surface water at that time.

In the San Juan Archipelago the dominant diatoms were *Thalassiosira Nordenskioeldii* and *Thalassionema nitzschioides* in samples taken between Reid Rock-Thatcher Pass and Thatcher Pass-Lowell Point, respectively. However, the plankton contained both species in all seven samples, together with numerous other species and a few thecate dinoflagellates. The plankton was rather dense in the first four samples, but between Deception Pass and Camano Head it greatly diminished in quantity.

South of Lowell Point the diatom-dominant plankton rapidly changed to one composed mainly of thecate dinoflagellates of the genera *Peridinium*, *Dinophysis*, and *Ceratium*, together with quite a number of ciliates of the genera *Favella*, *Helicostomella*, *Tintinnus*, and *Tintinnopsis*. This type of plankton continued from Lowell Point to Dash Point. Between Dash Point and Point Defiance the plankton was a mixture of that in the area just crossed and that found in the section south of Point Defiance.

The plankton in this southern section of Puget Sound was dominated by diatoms. As the southern end was approached all genera practically disappeared except *Chaetoceros* and many of the cells of its species contained resting spores, indicating the termination of growth for the season. The generalization may be readily made that *Chaetoceros* was the dominant genus on the cruise from Point Defiance to the head of Case Inlet.

The plankton, composed mainly of dinoflagellates and ciliates, found in Colvos Passage was similar to that in the passage to the east of Vashon and Maury Islands on the outgoing trip. It was unchanged from Point Defiance to Foulweather Bluff, via Colvos Passage.

In Hood Canal *Eucampia zoodiacus* dominated the plankton from its mouth to Capstan Rock, about two-thirds the distance of the inlet. From there to the head of the Canal at Lynch Cove and return *Dactyliosolen mediterraneus* was the most conspicuous species of diatoms. The plankton also contained a large portion of dinoflagellates

and zooplankton (larval stages of marine worms, crabs, clams, etc.). The return trip from Tekiu Point to the mouth of the Canal was similar to the incoming one except that the dinoflagellates had increased about twofold.

Across Admiralty Inlet to Possession Sound the plankton was rather nondescript, consisting of diatoms, dinoflagellates, and ciliates in about equal portions, together with quite a few larval forms of zooplankton. From Possession Sound to the end of the cruise diatoms of the species *Thalassiosira Nordenskioeldii* and *T. rotula*, and *Thalassionema nitzschioides* again dominated the plankton, except for the last two samples when *Sceletonema costatum* was overwhelmingly present.

SUMMARY

1. A study has been made of the variations of the physical and chemical properties and the plankton of the inland surface waters of the San Juan Archipelago, Puget Sound, and Hood Canal.

2. The waters of the different estuaries of the regions showed considerable variations as to distribution of plankton as well as physical and chemical properties.

3. The surface temperatures for the entire region studied ranged from 9.89° C., to 18.00° C., the chlorinities varied from 1.56 $^0/_{00}$ to 16.55 $^0/_{00}$, the phosphates from 0 to 1.25 x 10^{-3} mg. at. of phosphorus per kilo, the silicates from 1.3 to 7.2 x 10^{-2} mg. at. of silicon per kilo, and the nitrites from 0.00 to 0.73 x 10^{-3} mg. at. of nitrogen per kilo.

4. In many of the areas, conditions of "super-saturation" of dissolved oxygen were observed, while in others values as low as 50% saturation were secured.

5. The pH values, uncorrected for salt error, varied from 7.90 to 8.80, using cresol red as the indicator.

6. Three groups of microplankton were observed and investigated. *Diatomaceae* were represented by 17 genera and 41 species; *Dinoflagellata*, by 10 genera and 18 species; *Tintinnoinea*, by 7 genera and 17 species.

7. The plankton varied in the different areas both as to species and quantity.

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